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RESOLVING TOPOGRAPHIC DETAIL ON VENUS BY MODELING COMPLEX MAG-
ELLAN ALTIMETRY ECHOES; Amy J. Lovell, F. Peter Schloerb, Department of Physics and
Astronomy; George E. McGill, Department of Geology and Geography, University of Massachusetts,
Amherst MA 01003, USA.

Magellan's altimeter is providing some of the finest resolution topography of Venus achieved to date. Nevertheless, efforts continue to improve the topographic resolution whenever possible. One effort to this end is stereoscopic imaging, which provides topography at scales similar to that of the SAR. However, this technique requires two SAR images of the same site to be obtained and limits the utility of this method. In this paper, we present another method to resolve topographic features at scales smaller than that of an altimeter footprint, which is more globally applicable than the stereoscopic approach.

Each pulse which is transmitted by Magellan's altimeter scatters from the planet and echoes to the receiver, delayed based on the distance between the spacecraft and each surface element. As resolved in time, each element of an altimetry echo represents the sum of all points on the surface which are equidistant from the spacecraft. Thus, individual returns, as a function of time, create an echo profile which may be used to derive properties of the surface, such as the scattering law or, in this case, the topography within the footprint. The Magellan project has derived some of this information by fitting model templates to radar echo profiles. The templates are calculated based on Hagfors' Law [1], which assumes a smooth, gently undulating surface. In most regions these templates provide a reasonable fit to the observed echo profile; however, in some cases the surface departs from these simple assumptions and more complex profiles are observed. Specifically, we note that sub-footprint topographic relief apparently has a strong effect on the shape of the echo profile.

An echo profile which is misshapen by sub-footprint scale topography contains information about the surface topography at higher resolution than is normally available. Unfortunately, since it is impossible to invert an echo profile directly into a topographic distribution, it is necessary to have some knowledge about the surface which creates the echo in order to utilize this additional information. Investigation of SAR mosaics provides many constraints on the two-dimensional distribution of topography. Such insight into the appearance of the surface at these scales allows parameterization of new topographic models which can be used to derive sub-footprint topography.

To demonstrate the effects of sub-resolution relief on echo profiles, we have calculated the echo shapes from a wide range of simple topographic models. At this point, our topographic models have emphasized surfaces where only two dominant elevations are contained within a footprint, such as graben, ridges, crater rims, and central features in impact craters. Fortunately, these are features for which improved resolution is highly desirable. For example, the depths of grabens can be related directly to total extension if the attitude of the bounding faults are known or can be reasonably inferred. Moreover, crater morphometry provides important constraints on the energy of the impact event and on the rheological properties of the target materials.

Model surfaces are constructed on a Cartesian grid which lies at a given distance from the spacecraft. The heights of the elements in the grid are adjusted to simulate a particular surface feature, and a model echo is constructed by summing the contributions of scattering from each surface element. Assuming that each individual element scatters according to Hagfors' law, echoes which more closely approximate the complex Magellan profiles are constructed. In general, topographic relief below the average value within the footprint will create additional echo features on the trailing edge of the echo profile, while features due to elevated relief will appear on the leading edge. The time difference between the two superposed echoes is directly related to the vertical separation of the two regions in space, and by measuring this value, the relative elevations of features which are smaller than an altimeter footprint can be determined.

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An example of a surface feature which illustrates the usefulness of this approach is the crater Duncan (68N, 292E), shown in Figure 1 with overlaid altimetry footprints for orbits 2035 to 2040. Figure 2 shows the successive echo profiles stepping across the crater from the east (orbits 2040 through 2035, footprint -769). The altimetry echoes which incorporate the rim (panels 3 and 4) have two distinct components, one corresponding to the crater floor, the other to the rim. The temporal resolution between the two components is on the order of $4 \mu\text{s}$, corresponding to a height difference of 650 meters. Since the origin on the time axis corresponds to the crater floor, the earlier echoes (those at negative time offset) must correspond to higher elevations, i.e. the rim and surrounding terrain. In this way, the depth of the crater can be determined even in cases where there is not an entire altimetry footprint on the floor of the crater.

In conclusion, we have demonstrated a method for using Magellan altimetry echoes to improve topographic resolution on Venus. Currently, this method applies only to relatively simple features with two dominant elevations. However, we believe that in the future, the method can be extended to apply to slightly more complex features, such as ridge belts and other topographic distributions containing several distinct elevations.

[1] Hagfors, T. (1970) *Radio Science*, 5, pp. 189-227.

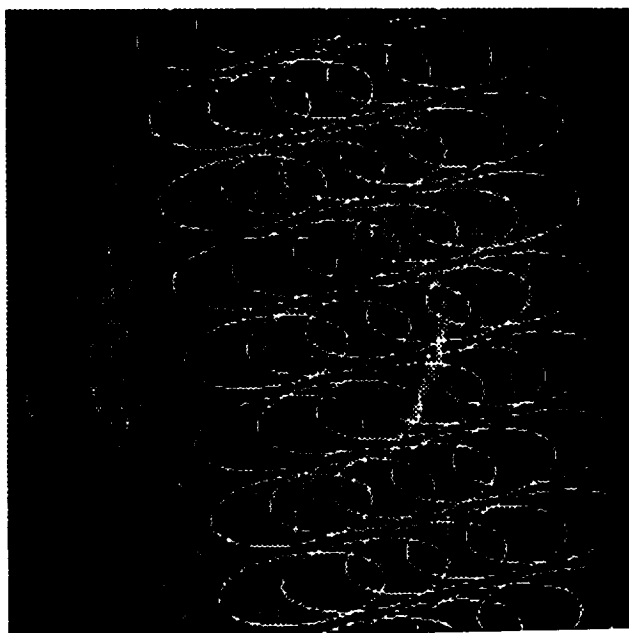


Figure 1: Crater Duncan showing altimetry footprints for orbits 2035 to 2039.

Figure 2: (right) Altimetry echo profiles for footprint -769 in 6 orbits. Top to bottom moves east to west across the lower half of crater Duncan.

